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RESEARCH MEMORANDUM

for the

Air Materiel Command, U. S. Air Force

PERFORMANCE OF ALLISON MODEL 400-C6 TURBOJET-ENGINE

COMPRESSOR

I - OVER-ALL PERFORMANCE CHARACTERISTICS OF COMPRESSOR

AT EQUIVALENT IMPELLER SPEEDS

OF 6000, 7000, AND 8500 RPM

By Karl Kovach and Joseph R. Withee, Jr.

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NATIONAL ADVISORY COMMITTEE
FOR AERONAUTICS
WASHINGTON

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I - OVER-ALL PERFORMANCE CHARACTERISTICS OF COMPRESSOR

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SUMMARY

The Allison model 400-C6 compressor was operated at an inlet
pressure of 12 inches of mercury absolute and ambient inlet tempera-
ture at equivalent impeller speeds of 6000, 7000, and 8500 rpm.
Additional runs at an equivalent speed of 7000 rpm and ambient inlet
temperature were made at inlet pressures from 7 to 22 inches of mercury
absolute. The results of this investigation are compared with those
of the J33-A-23 compressors.

For the speeds investigated, the Allison model 400-C6 compressor
had a maximum adiabatic temperature-rise efficiency of 0.768 at an
equivalent speed of 7000 rpm; the corresponding equivalent weight
flow was 45.0 pounds per second and the pressure ratio was 1.83. At
an equivalent impeller speed of 8500 rpm, the maximum equivalent
weight flow was 61.6 pounds per second and the peak pressure ratio
of 2.38 occurred at an equivalent weight flow of 52.2 pounds per
second and an adiabatic temperature-rise efficiency of 0.714.

At an equivalent speed of 7000 rpm, increasing the compressor-
inlet pressure increased the maximum equivalent weight flow and the
pressure ratio.

At the maximum comparable equivalent impeller speed of 8500 rpm,
the maximum equivalent weight flow was approximately 6.5 percent
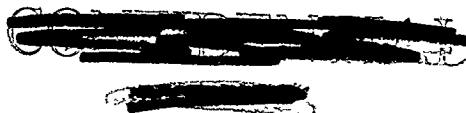
higher than the weight flow for the J33-A-23 compressor with a 34-
blade impeller. The pressure ratio and the adiabatic temperature-
rise efficiency were slightly lower than those of the J33-A-23 com-
pressors; however, a comparison of pressure ratio and efficiency
at low speeds is not necessarily indicative of a comparison at high
speeds.

INTRODUCTION

At the request of the Air Materiel Command, U. S. Air Force, an
investigation is being conducted at the NACA Lewis laboratory to
determine the performance characteristics of a series of turbojet-
engine compressors. An investigation of an Allison model 400-C6
turbojet-engine compressor is presented. Runs were made over a
range of equivalent impeller speeds from 6000 to 8500 rpm with an
inlet pressure of 12 inches of mercury absolute and ambient inlet
temperature. Additional runs were made at an equivalent impeller
speed of 7000 rpm, ambient inlet temperature, and various inlet pres-
sures to determine the effect of inlet pressure (Reynolds number) on
compressor performance. The investigation was terminated by failure
of the compressor unit.

APPARATUS AND INSTRUMENTATION

Apparatus. - The Allison model 400-C6 compressor assembly con-
sists of a double-entry centrifugal compressor, a vaned diffuser,
and a compressor casing. The compressor dimensions are:

Impeller-inlet diameter, inches 19.48
Impeller-outlet diameter, inches 30.00
Number of impeller blades, per side 23
Diffuser-inlet-vane diameter, inches 33.24
Number of diffuser passages 14
Mean diffuser-discharge diameter, inches 42.88
Diffuser-outlet passage area, square inches per passage . . . 10.41

The remainder of the apparatus is the same as that described in refer-
ence 1.

Instrumentation. - The instrumentation is also the same as that
described in reference 1 with the exception that a submerged flat-
plate orifice was used to measure the compressor air weight flow.

The precision of the measurements is estimated to be within the following limits:

Temperature, $^\circ$F . . . . ±0.5
Pressure, inches mercury absolute . . . . ±0.04
Air weight flow, percent . . . . ±1.0
Impeller speed, percent . . . . ±0.3

SYMBOLS

The following symbols are used in this report:

N   impeller speed, rpm

P_1 inlet total pressure, inches mercury absolute

P_2 outlet total pressure, inches mercury absolute

Q   volume flow, cubic feet per second

T_1 inlet total temperature, $^\circ$R

U   impeller tip speed, feet per second

W   weight flow, pounds per second

δ ratio of inlet total pressure to NACA standard sea-level
         pressure

η_{ad} adiabatic temperature-rise efficiency

θ ratio of inlet total temperature to NACA standard sea-level
         temperature

μ absolute viscosity, pounds per foot-second

METHODS

The runs to determine the over-all performance characteristics
of the compressor were made at ambient inlet temperature, which varied
from 78° to 86° F, and at the highest inlet pressure possible at design

speed as limited by the power and the gear ratio of the drive unit. A summary of the operating conditions is given in the following table:

Equivalent impeller speed $N/\sqrt{\theta}$ (rpm)	Equivalent tip speed $U/\sqrt{\theta}$ (ft/sec)	Inlet pressure P_1 (in. Hg abs.)	Effect determined
6000	786	12	Speed and
7000	916	12	air-flow
8500	1113	12	rate
7000	916	7	Inlet pressure
7000	916	9	(Reynolds
7000	916	17	number)
7000	916	22	

RESULTS AND DISCUSSION

Effect of speed. - The performance of the Allison model 400-C6 compressor at equivalent impeller speeds of 6000, 7000, and 8500 rpm is presented in figure 1. For these speeds, the maximum adiabatic temperature-rise efficiency was 0.768 and occurred at an equivalent impeller speed of 7000 rpm, an equivalent weight flow of 45.0 pounds per second, and a pressure ratio of 1.83. At an equivalent impeller speed of 8500 rpm, the maximum equivalent weight flow was 61.6 pounds per second, and the peak pressure ratio of 2.38 occurred at an equivalent weight flow of 52.2 pounds per second and an adiabatic temperature-rise efficiency of 0.714.

Effect of inlet pressure (Reynolds number). - The effect of inlet pressure (Reynolds number) on compressor performance for an equivalent impeller speed of 7000 rpm is shown in figure 2. For convenience, this effect is shown in terms of a Reynolds number index $P_1/(\mu\sqrt{T_1})$. Because the inlet temperature was held as nearly constant as possible, changes in μ and $\sqrt{T_1}$ are very small and the principal variable is inlet pressure P_1. Increasing the Reynolds number by increasing the inlet pressure resulted in higher maximum equivalent weight flow and pressure ratio.

Comparison of performance of J33-A-23 compressors with Allison model 400-C6 compressor. - Peak performance characteristics of the J33-A-23 compressors and the Allison model 400-C6 compressor are

compared in figure 3 for equivalent impeller speeds of 6000, 7000, and 8500 rpm. The comparison is not exact because of the difference in the operating conditions between the model 400-C6 compressor and the J33 compressors. The model 400-C6 compressor was run at an inlet pressure of 12 inches of mercury absolute and the J33 compressors were run at an inlet pressure of 14 inches of mercury absolute. It can be seen from figure 2 that a slight increase in compressor performance would be obtained if the model 400-C6 compressor were operated at an inlet pressure of 14 inches of mercury absolute.

The weight-flow capacity of the model 400-C6 compressor is greater than the weight-flow capacity of the J33-A-23 compressors (fig. 3(a)). At an equivalent impeller speed of 8500 rpm, the maximum equivalent weight flow is approximately 6.5 percent higher than the weight flow for the J33-A-23 compressor with a 34-blade impeller. The peak pressure ratio for the model 400-C6 compressor is very slightly lower than the peak pressure ratio for the J33-A-23 compressors. At an equivalent impeller speed of 8500 rpm, the peak adiabatic temperature-rise efficiency for the model 400-C6 compressor was approximately 0.04 lower than the efficiency for the J33-A-23 compressor with a 17-blade impeller, and approximately 0.02 lower than the efficiency for the J33-A-23 compressor with a 34-blade impeller. This comparison of pressure ratio and efficiency at low speeds is not necessarily indicative of a comparison at high speeds. In fact, the better a unit is at the design point, the poorer it is likely to be at off-design points.

SUMMARY OF RESULTS

An investigation of the over-all performance characteristics of the Allison model 400-C6 compressor gave the following results:

1. When operated at equivalent impeller speeds of 6000, 7000, and 8500 rpm, the compressor had its maximum adiabatic temperature-rise efficiency of 0.768 at an equivalent impeller speed of 7000 rpm with an equivalent weight flow of 45.0 pounds per second and a pressure ratio of 1.83. At an equivalent impeller speed of 8500 rpm the maximum equivalent weight flow was 61.6 pounds per second and the peak pressure ratio of 2.38 occurred at an equivalent weight flow of 52.2 pounds per second and an adiabatic temperature-rise efficiency of 0.714.

2. At an equivalent impeller speed of 7000 rpm, increasing the compressor-inlet pressure resulted in higher maximum equivalent weight flow and pressure ratio. This variation of compressor performance with inlet pressure indicates a Reynolds number effect.

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3. At the maximum comparable equivalent impeller speed of 8500 rpm, the maximum equivalent weight flow was approximately 6.5 percent higher than the weight flow for the J33-A-23 compressor with a 34-blade impeller. The pressure ratio and the adiabatic temperature-rise efficiency were slightly lower than those of the J33-A-23 compressors; however, a comparison of pressure ratio and efficiency at low speeds is not necessarily indicative of a comparison at high speeds.

Lewis Flight Propulsion Laboratory,
    National Advisory Committee for Aeronautics,
        Cleveland, Ohio, December 15, 1948.

Karl Kovach,
Aeronautical Research Scientist.

Joseph R. Withee, Jr.,
Aeronautical Research Scientist.

Approved:
            Robert O. Bullock,
   Aeronautical Research Scientist.

            , Oscar W. Schey,
   Aeronautical Research Scientist.

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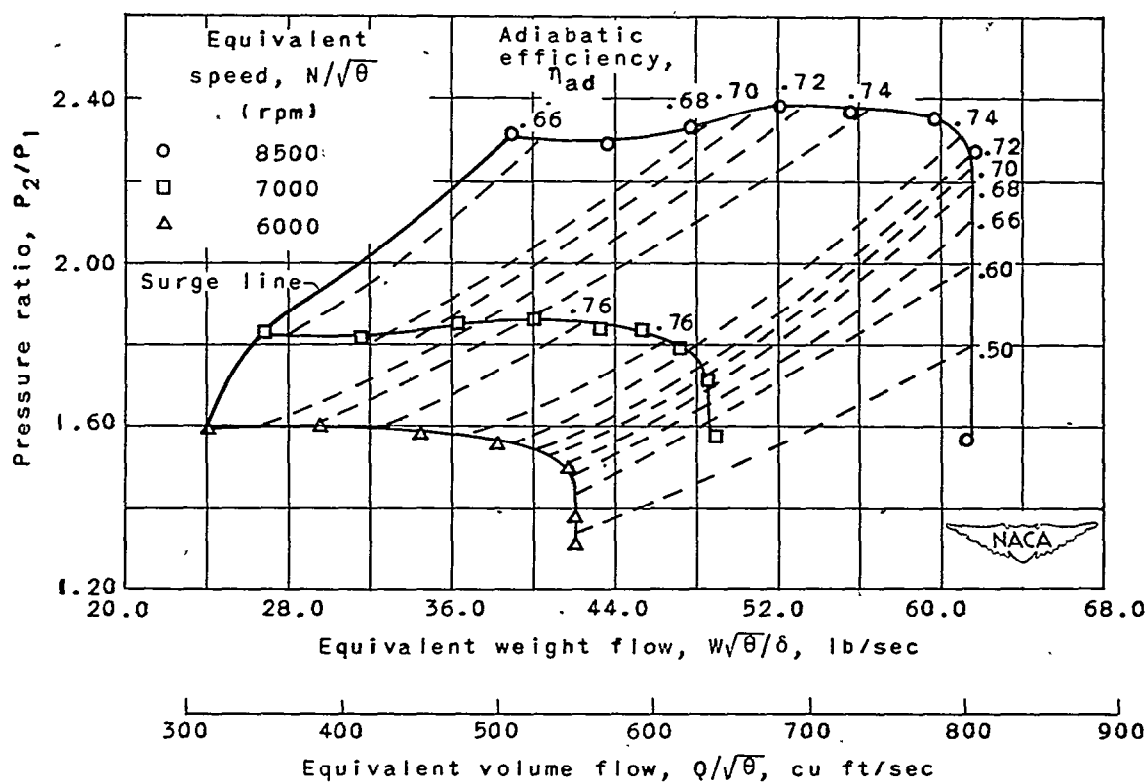
(a) Pressure ratio.

Figure 1. — Performance of 400—C6 compressor at inlet pressure
of 12 inches mercury absolute and ambient inlet temperature.
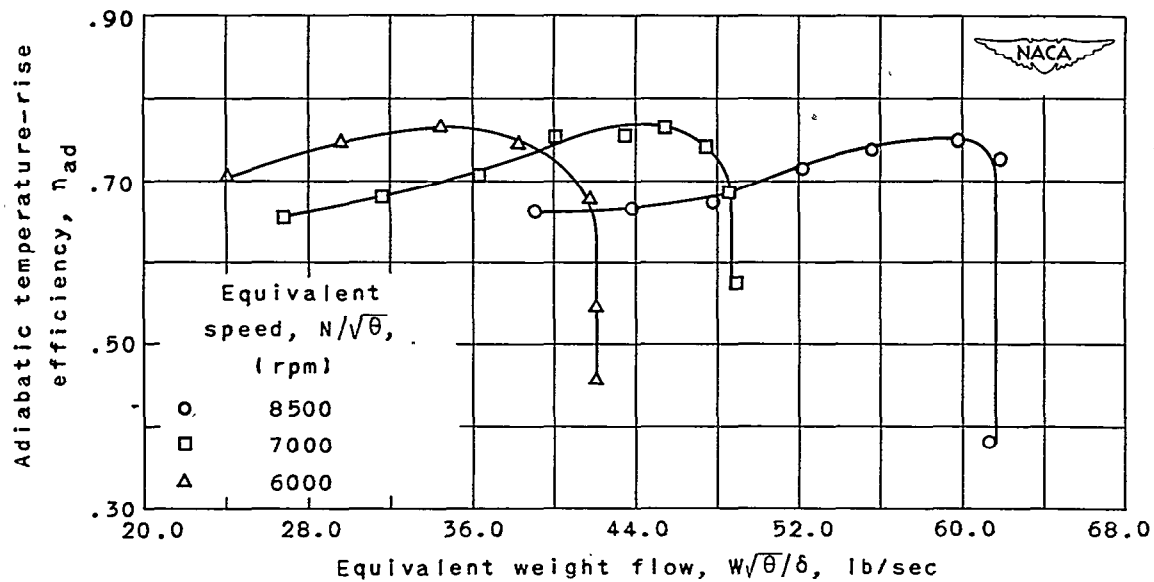
(b)   Adiabatic temperature-rise efficiency.

Figure I. - Concluded. Performance of 400-C6 compressor at
   inlet pressure of 12 inches mercury absolute and ambient
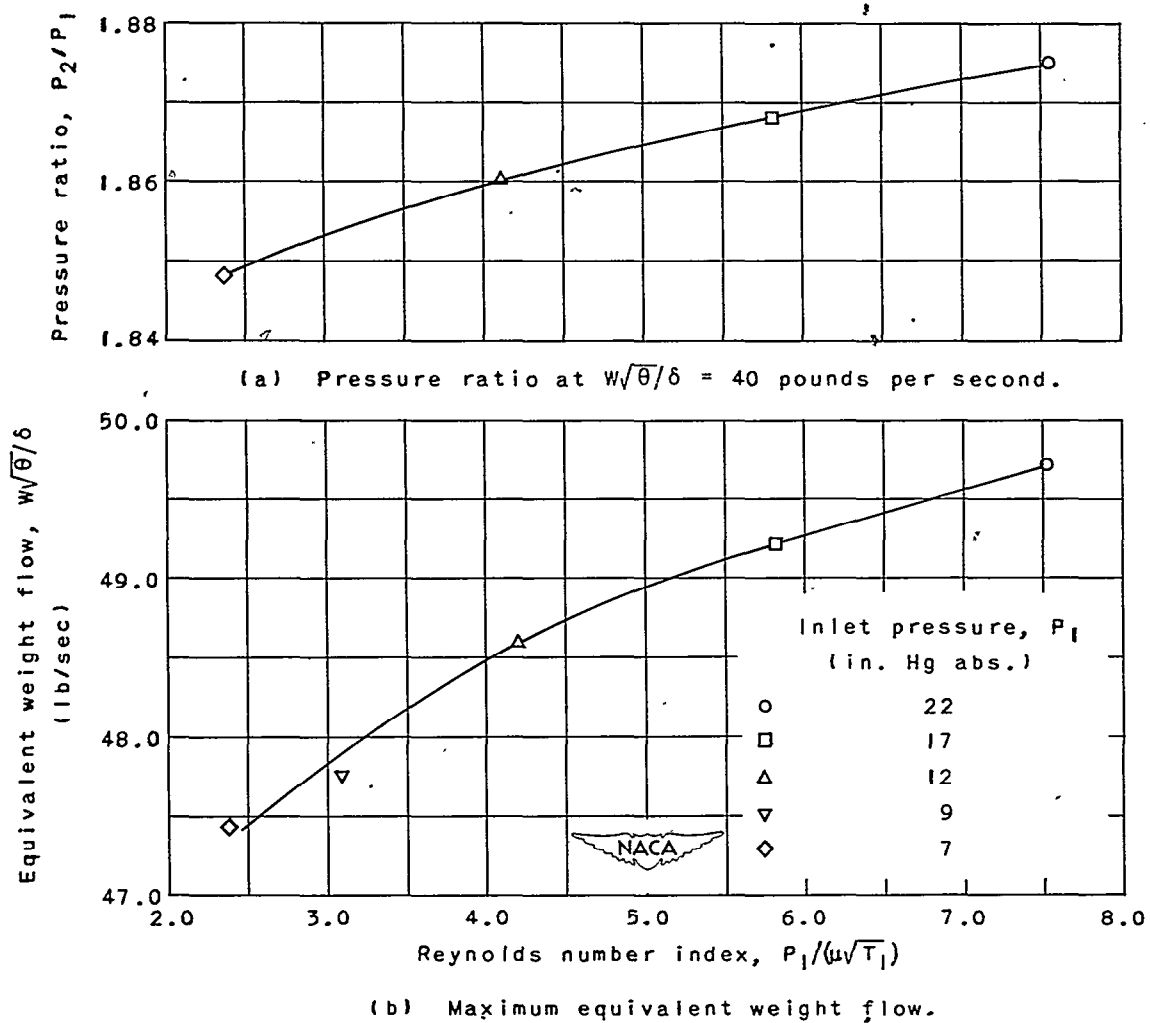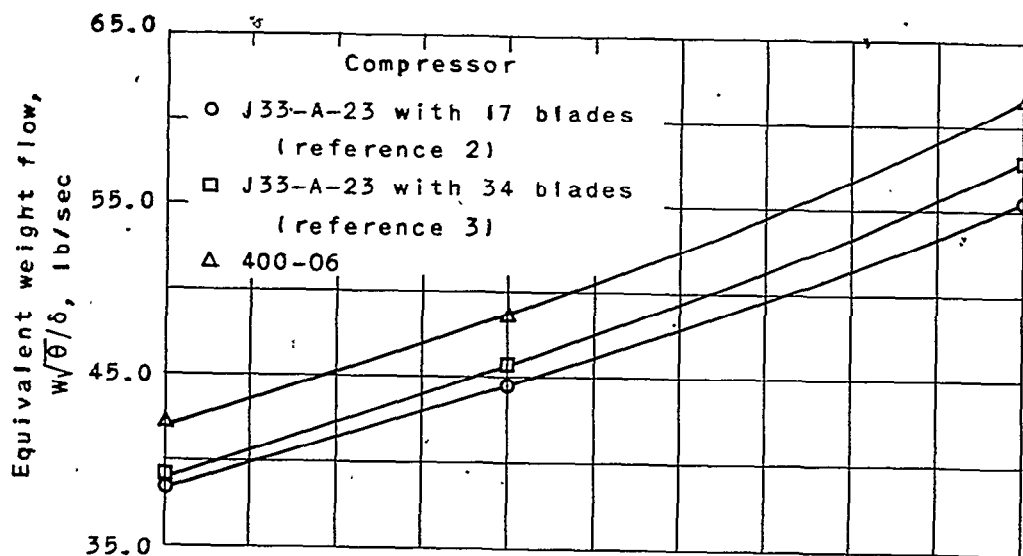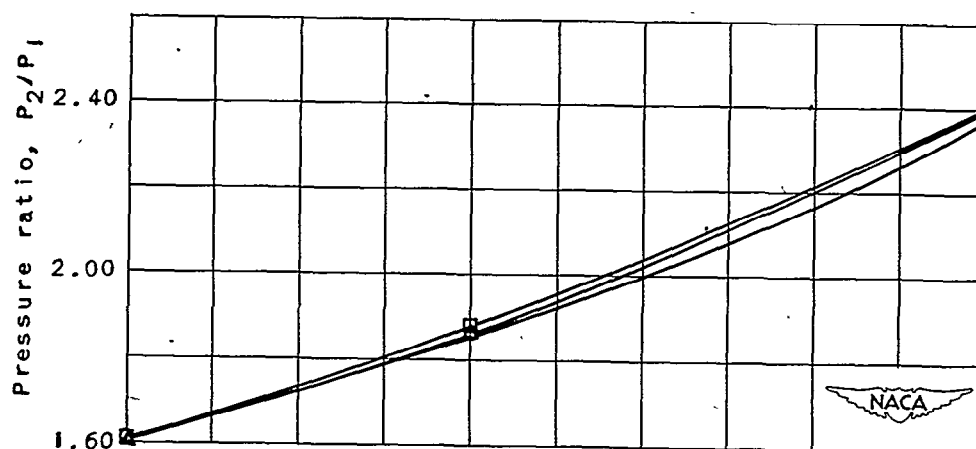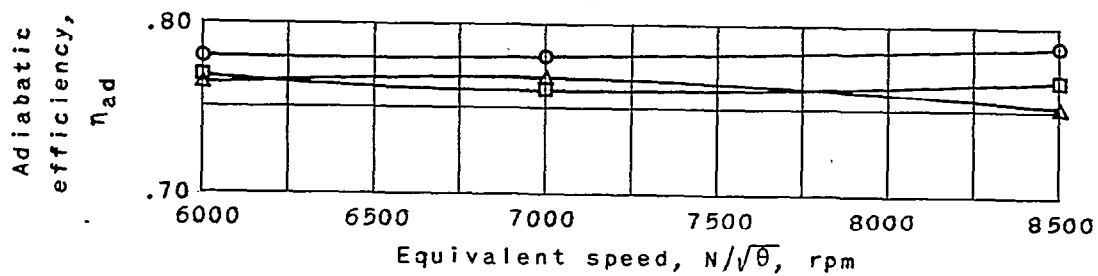   inlet temperature.

(a)   Pressure ratio at $W\sqrt{\theta}/\delta$ = 40 pounds per second.

(b)   Maximum equivalent weight flow.

Figure 2. – Effect of Reynolds number on 400–C6 compressor
performance at equivalent impeller speed of 7000 rpm and
ambient inlet temperature.

(a)   Maximum equivalent weight flow.

(b)   Peak pressure ratio.

(c)   Peak adiabatic temperature-rise efficiency.

Figure 3. - Comparison of 400-C6 compressor with J33-A-23 compressors.